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PAPER-PENCIL LABORATORY ACHIEVEMENT TESTS IN PHYSICS

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Abstract

The paper lists a number of typical specific skills and abilities associated with laboratory instruction in elementary physics. The list served as a guide in the construction of a number of multiple-choice laboratory tests in Mechanics, Heat, Sound, and Electricity. The individual tests are described and typical items from each test are reproduced. Some of the tests were tried on students in three elementary physics courses at the University of Minnesota, and the frequency distributions of scores are given. A subsequent report will describe the work on the comparisons between paper-pencil and performance tests as well as their relations to other achievement measures.

Paper-Pencil Laboratory Achievement Tests in Physics*

Laboratory work in elementary college physics is evaluated in most schools almost entirely by means of laboratory reports written by the student outside the classroom. The need for more precise instruments for measuring laboratory achievement has been pointed out elsewhere (1,2). Since laboratory work consists of performance and intellectual operations by the student, it is reasonable to postulate a two-dimensional evaluation approach: by means of performance tests and paper-pencil examinations. In a previous report (1) the construction, administration, and characteristics of performance tests were described. An inspection of the existing standardized tests in college and high school physics revealed practically no questions directly related to laboratory work. Therefore it became necessary to initiate a program of paper-pencil test construction to parallel the investigation on performance items.

Conference with Consultants

A one-day conference was held at the University of Minnesota on June 16, 1952. The object of the conference was to review the work on performance tests in physics and to discuss plans for future research. Present were Professors G. Freier, R. Goodwin, L. Nedelsky, D. Roller, and C. N. Wall, the consultants for the project, Dr. C. Hoyt, the Director of the Bureau of Educational Research, and Dr. H. Kruglak, the Principal Investigator. The latter reviewed the purpose of the project and the work already accomplished. The group was taken through the general physics laboratories to examine the performance items which had been left set up at the locations after the spring quarter examinations. The consensus of the group was that the evaluation of laboratory teaching in physics is

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an extremely important problem. It was also brought out that if valid paper-pencil tests could be developed, much of the labor involved in setting up and grading performance tests might be eliminated.

The conferees agreed on the desirability of drawing up a list of objectives which would define specific skills and abilities characteristic of the physics laboratory. Examples of such objectives were given: translation from symbol to real object and vice versa, estimate of an error, evaluation of measuring instruments in terms of zero setting and uniformity of scale, etc. After constructing items for specific objectives, a master list of the items with a key would be sent to cooperating institutions with a request for an appraisal of the items. Thus, along each item there might be provided a place for checking one of the choices:

( ) the item is very much like the skill or ability the student used in the lab

( ) " " " somewhat " " " " " " " " " " " "

( ) " " " not at all " " " " " " " " " " " "

Another approach would be to send a list of skills relevant to laboratory work with a request for a definition of each skill and a description of a skill not named on the list, with specific examples.

Development of Paper-Pencil Tests

On July 10, 1952, Dr. C. N. Wall and H. Kruglak met to discuss plans for carrying out the recommendations of the conference. It was agreed to concentrate on the development of tests, each of which would (a) measure a very narrow range of skills, (b) be relatively easy to construct. The following typical rather than exhaustive list of specific objectives was compiled.

1. Identification of apparatus from photographs, diagrams, and descriptions.

2. Knowledge of the function of apparatus, materials, and instruments.
3. Reading instruments commonly found in the physics laboratory.
4. Symbolic representation of real objects and identification of objects from their symbolic representation.
5. Selection of apparatus for specific measurement or function.
6. Calculation procedure from specific data.
7. Reading and intrepretation of graphs.
8. Drawing a graph from a set of experimental data.
9. Understanding directions for carrying out a specific laboratory procedure.
10. Recognition of random and systematic errors. Making an error analysis from experimental data.

A number of tests were developed with the above ideas in mind. In selecting appropriate items, the test constructors consulted a large number of laboratory manuals, manufacturer direction sheets for special apparatus, and catalogs of scientific equipment. Mr. R. V. Stuart developed most of the items in Mechanics, Heat, and Sound. Mr. K. Quisenberry was responsible for most of the electricity items. As in the case of the performance tests, the paper-pencil items were sent to the four consultants for rating on a three-point scale: good, fair, and poor. Considerable effort and time were required in finding drawings and photographs that could be reproduced with sharp detail. All the items were of the multiple choice, five-alternative type. Each test will be described briefly as to the particular skills it purports to measure. Some typical items will be reproduced, and the score distributions will be given for the tests that have been administered. The scoring formula for each test was $4R-W$, where R is the number of correct responses and W is the number of wrong responses.

Description of Tests

Error Analysis

This test was designed to sample the skills acquired for: calculating random and systematic errors from experimental data typical of laboratory work in elementary physics; handling significant figures; deriving error equation for a given physical relationship; evaluating critically experimental data for consistency; determining the absolute and per cent accuracy of an instrument from a photograph of its scale; expressing the accuracy of a physical measurement from a description of the limiting accuracy of the measuring instruments.

The test consists of 68 items. It has not been administered to any group to date. Following is an item which received a top rating from all the four consultants.

( ) A question often asked is: Could you use 22/7 as the value of π in an experiment:

(a) This is a catch question since 22/7 is the value of π .

(b) The answer is invariably "yes" since the difference between 22/7 and π is not enough to make any difference.

(c) It is permissible to use 22/7 for π if you make the indeterminate (random) error larger than the difference.

(d) Since you don't measure π , it doesn't introduce any error in the experiment so 22/7 is an acceptable value.

(e) You can use 22/7 as the value of π if some of the measured quantities are measured to only three significant figures.

Reading Instruments

This test consists of four parts, each designed to evaluate the subject's ability to read the scales of instruments commonly used in the elementary physics laboratory. Part I has 20 questions on the vernier caliper. The main scale and the vernier are reproduced in one diagram with the zeros of both coincident so as to enable the student to find the least count of the instrument. The instrument is then shown with the jaws closed. The subject is asked to determine the magnitude and sign of the zero error. Another drawing of the same vernier is labeled "jaws closed on an object". The testee is asked for a reading of the instrument. Verniers with a variety of scales were used. Part II contains 16 items on micrometers. The items are similar to those in Part I. Part III has 12 items designed to appraise the student's ability to read stop watches. The watch faces are reproduced photographically, approximately full size. Part IV has 16 items designed to determine the student's skill in reading the scales of a meter stick, protractor, graduate cylinder, analytical balance, spring balance, thermometer, and hydrometer. Some of the scales are photographic reproductions; others are schematic drawings.

None of the items in the Reading Instruments Tests have been tried on any group. Two items from Part I are reproduced below.

( ) Refer to diagram #1. (See Figs. 1&2, Appendix A) The zero error of vernier caliper #111 is

(a) 0.01 cm to be subtracted from all readings.

(b) 0.09 cm to be subtracted from all readings.

(c) 0.08 cm to be subtracted from all readings.

(d) 0.01 cm to be added to all readings.

(e) 0.09 cm to be added to all readings.

( ) Refer to diagram #2. The reading of vernier caliper #111 in diagram #2 is

(a) 10.06 cm.

(b) 10.60 cm.

(c) 10.66 cm.

(d) 16.06 cm.

(e) 16.60 cm.

Identification of Apparatus-Mechanics

The purpose of this test is to find out how familiar the subject is with various pieces of equipment used in performing experiments in Mechanics. Each of the thirty items refers to each of the thirty photographs of devices and instruments. The subject is to identify each piece of apparatus shown in the figures. The test was administered to 118 students in Physics 1 and 166 students in Physics 1a, fall quarter 1952, as a pre-test, and as a post-test to 53 and 70 students respectively. The Physics 1 course is offered without laboratory; students in Physics 1a had the conventional laboratory experiences.

The frequency distributions of scores are shown in Appendix B_1. A typical item is reproduced below.

( ) Picture 3 shows (See Fig. 3, Appendix A)

(a) plumb bob, (b) spark recorder, (c) buzzer, (d) stylus, (e) drawing pen.

Function of Apparatus-Mechanics

This test was designed to measure the student's understanding of the most common use of the various devices in performing mechanics experiments. The thirty items are based on the same photographs as the Identification of Apparatus

Test. The Function of Apparatus Test was also administered to the Physics 1 and 1a students. The frequency distributions for the pre-test and post-test scores are shown in Appendix B_2. Following is an item from the test:

( ) The apparatus shown in Figure 3 is used to (See Fig. 3, Appendix A)

a. receive code.

b. record a timed oscillatory trace.

c. letter drawings.

d. rule lines on metal or wood.

e. align points vertically.

Experiments-Mechanics

In this test the examinee is shown a photograph of apparatus designed to measure a given physical quantity. He is asked for additional apparatus, to be selected from another series of photographs, needed to yield sufficient data for calculating the required quantity. The Experiments Test was given to the Physics 1, 1a groups as a pre-test and post-test. The frequency distributions of the scores are given in Appendix B3. One of the 15 items in the test is reproduced below.

( ) The set of apparatus shown in picture 4 is to be used in obtaining the data necessary for finding the coefficient of friction by the inclined plane method. To yield sufficient data the set of apparatus labeled #4 (See Fig. 4, Appendix A)

A. and items W and X are necessary

B. and items X and Y are necessary

C. and items W, Y, and Z are necessary

D. and item Z are necessary

E. includes the <u>minimum</u> equipment necessary

Miscellaneous-Mechanics

This test consists of two parts, each having seven items. In part 1 there are shown five dimensions on photographs of physical apparatus. The subject is asked to select the most appropriate measuring instrument out of the seven shown in another part of the picture. In part 2 the subject is to identify two components that are used together, or are parts of the same apparatus. The test was also administered to the groups mentioned in connection with the previous three tests in Mechanics. The score distributions are shown in Appendix B_4.

Heat

The 21 items in this test are based on a set of 31 photographs of apparatus commonly used to perform the conventional experiments in heat. The items call for identification of the apparatus, recognition of its function, and the selection of minimum apparatus for getting sufficient data to determine a given physical quantity. This test has not been administered to date. Following is an item from the test.

Assume expendables such as gas, electricity, water, ice, and rubber tubing to be available as needed. In the following question you are given a list of items, from which you can determine the experiment to be performed. Following the list are five corrections of which only one is proper. Record the letter corresponding to the proper correction. If an item is not useful in the experiment a correction is needed.

( ) A student requests the apparatus shown in pictures 2, 8, 26, (See Fig. 5, appendix A) and the necessary electrical apparatus. These items will yield sufficient data with the following correction to the list of items.

(a) include item 24

(b) eliminate item 8

(c) include items 4 and 24

(d) no correction needed

(e) include item 24 and eliminate item 2

Some of the consultants felt that the above item was too difficult for the elementary students. It was suggested that the name of the experiment to be performed should be added. The items were revised so as to include the object of the experiment.

Sound

The items in this test sample skills similar to those mentioned in the test on Heat. There are 20 photographs of apparatus commonly used in basic experiments on sound; the 21 items refer to the photographs. The test has not yet been tried on any students.

Identification of Apparatus—Electricity

From a photograph of 54 pieces of electrical apparatus, the examinee identifies a particular one by associating the number of the picture with one of the five terms listed in each item. Of the 22 items in this test 16 have been tried as a pre-test and post-test on one group of Physics 5 and one group of Physics 8 students at the University of Minnesota, winter quarter 1952. The frequency distributions of the scores are shown in Appendix C_1.

Function of Apparatus—Electricity

The items in this test are based on the same set of photographs as the previous test. The purpose of the test is to find out the extent of the student's familiarity with the use of the various pieces of electrical equipment. Of the 27 items 18 have been tried on the same groups as the Identification of Apparatus Test—Electricity. The frequency distributions of the scores are shown in Appendix C_1.

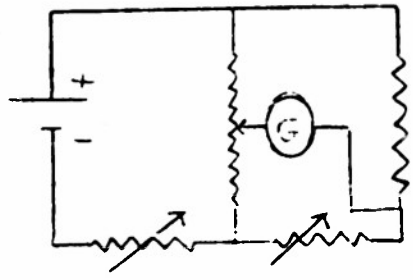
Function of Apparatus-Electricity

The items in this test are based on the same set of photographs as the previous test. The purpose of the test is to find out the extent of the student's familiarity with the use of the various pieces of electrical equipment. Of the 27 items 16 have been tried on the same groups as the Identification of Apparatus Test-Electricity. The frequency distributions of the scores are shown in Appendix C_1.

Electrical Circuits

This test consists of ten photographs of wired circuits with numbered components and terminals. The main purpose of the test is to assess the students skill in tracing circuits from schematic diagrams and vice versa. There are also items which sample the subject's ability to recognize the function of the circuit, the use of certain components and instruments in it, and knowledge of the operating characteristics of the assemblies and their parts. From the 45 available items of this test 26 have been selected and tired on the above mentioned groups of Physics 5 and 8 students. The frequency distributions of the scores are shown in Appendix C_3. An item from the test is reproduced below.

( ) Referring to the schematic diagram at the right the circuit in picture 6 is (See Fig. 6, Appendix A)



(a) wired exactly according to the schematic

(b) wired correctly except wires 2 and 3 should be reversed

(c) wired correctly except resistances 4-5 and 0-1 should be interchanged

(d) wired correctly except the battery wires should be reversed

(e) wired correctly except wire at 6 should be moved to 8.

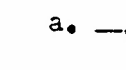
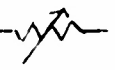
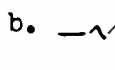
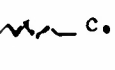
Electrical Meters

This test attempts to evaluate the students ability to read a fairly complex electrical meter. Four photographs of the front panel of the RCA Junior Volt Ohmist represent four different settings of the instrument, with the needle in operating position. Four of the eight questions ask for the identification of the quantity being measured; the remaining four items ask for the actual readings of the scale, with the units. This test was tried on the winter quarter groups in Physics 5 and 8. The frequency distributions of the scores are shown in Appendix C_3.

Symbols-Electricity-A

The object of the test is to find out to what extent the student understands the conventional symbols used in electricity and is able to assign a symbol to a piece of electrical equipment represented by a picture. The 25 items in the test refer to the photographs used in the identification and function tests for electricity. None of the items have been tried as yet. Following is an item from the test.

( ) Picture 7 (See Fig. 7, Appendix A) is best represented by symbol

a. b.  c.  d.  e. 

Symbols-Electricity-B

This test is designed to evaluate the subject's skill in recognizing a symbol from the name or the common use of a piece of electrical equipment. This test differs from the Symbols A Test in that the association in the former is made between a conventional symbol and a <u>verbal</u> definition or description of the apparatus. Of the 20 items in this test 15 have been tired on the Physics 5 and 8 groups. The score frequencies for the pre-tests and post-tests are shown in Appendix C_2. A typical item is reproduced below.

( ) Symbol 8 represents a (an) (See Fig. 8, Appendix A)

(a) inductance, (b) iron core transformer, (c) air core transformer, (d) potentiometer, (e) electromagnet.

Tests in Preparation

Two more tests are being prepared: Optics and Modern Physics. The test on optics is difficult to construct along the same lines as the tests in other divisions of physics. The chief difficulty lies in photographing or reproducing optical surfaces and images. However, work is in progress and there is reasonable assurance that satisfactory tests will be available shortly.

The Analysis of Test Results

The paper-pencil laboratory tests administered during 1952-53 are being analyzed. Particular emphasis will be placed on the investigation of the relationship between written test and the laboratory performance tests in the course sequence. In addition to the item analysis, correlation coefficients between the written and performance tests are being computed, as well as the written and performance test intercorrelations and the correlations between both forms of the laboratory test and other achievement measures in physics. It will also be of interest to know whether or not there have been any significant gains on each of the tests.

References

1. Kruglak, H. Laboratory Performance Tests in Physics. Technical Report No.1, ONR Project NR 153-148. Minneapolis: 1952. Physics Department, University of Minnesota

2. Wall, C. N., Kruglak H., & Trainor, L.E.H. Laboratory performance tests at the University of Minnesota. Am.J. Phys., 1951, 19,546-555.

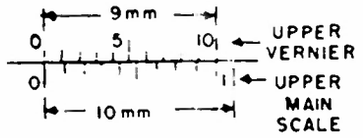
APPENDIX A

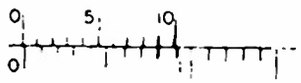
ILLUSTRATIONS FOR TEST ITEMS

VERNIER CALIPER # 111

THE UPPER MAIN SCALE IS GRADUATED IN MILLIMETERS

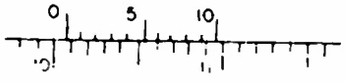
THE ENLARGED DIAGRAM IS SHOWN TO THE RIGHT





JAWS CLOSED TOGETHER

FIG. 1



JAWS CLOSED ON OBJECT

FIG.2

FIG.3

FIG. 4

W

X

Z

Y

FIG. 4

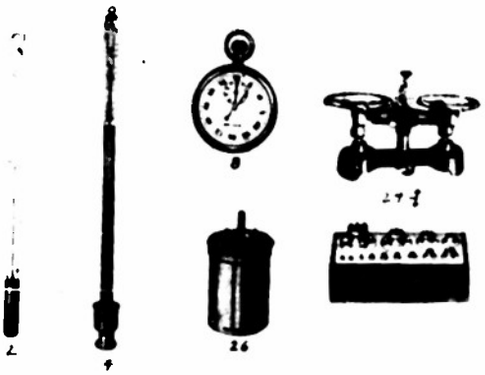


FIG. 5

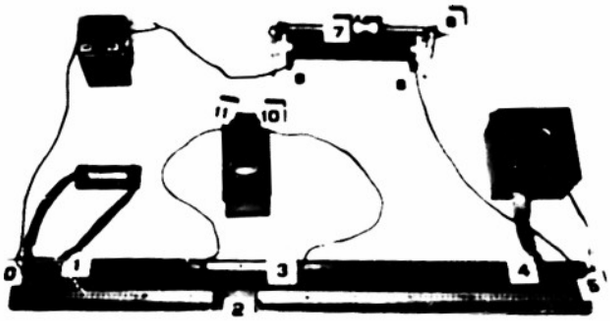


FIG. 6.

FIG. 7

FIG. 8

Appendix B1. Distribution of Test Scores. Identification of Apparatus-Mechanics

Maximum score 120. University of Minnesota Fall quarter 1952-53

Score	Physics 1-no laboratory				Physics 1a-with laboratory			
	male		female		male		female	
	pre	post	pre	post	pre	post	pre	post
109-111								
106-108						6		
103-105						2		
100-102	1					4		
97-99						1		
94-96		1			1	3		
91-93					1	2		
88-90						3		
85-87	2	1			6	2		
82-84		1				7		
79-81	2	5			4	8		
76-78		1			3	5		
73-75	2	3			3	2		
70-72	5	3		1	6	1		
67-69		3			4	3		2
64-66	1			1	4	5		1
61-63	3	1			4	4	1	
58-60	5		1		9	2		
55-57	10	7		1	7	1		1
52-54	1	1	2	1	5	2	1	
49-51	3	1	1	5	13			
46-48	5		2	2	7		2	
43-45	7	1	3	1	11	1	1	1
40-42	3		4	1	18			1
37-39	2		4	3	6			
34-36	5		4	1	7		2	
31-33	4	1	2	1	7		3	
28-30	1		6	2	4		2	
25-27		1	6	1	4		2	
22-24	1		1		3			
19-21			2		1		3	
16-18	2	1	1		2		2	
13-15	1		1		3		1	
10-12			2		1			
7-9			2					
4-6			1		1			
1-3			1					
-1-0							1	
N	72	32	46	21	145	64	21	6

Appendix B2. Distribution of Test Scores. Function of Apparatus-Mechanics

Maximum Score 120 University of Minnesota Fall quarter 1952-53

Score	Physics 1-no laboratory				Physics 1a-with laboratory			
	male		female		male		female	
	pre	post	pre	post	pre	post	pre	post
109-111	1							
106-108					1	1		
103-105						1		
100-102		2				1		
97-99						2		
94-96		1			2	4		
91-93		2			1	6		
88-90	2	2		1	1	6		
85-87	1	2			3	7		
82-84	1	3			5	4		
79-81	1	3			4	2		2
76-78	2	2			3	5		
73-75	6	2			7	7		
70-72	6	3			10	2		
67-69	3			1	4	2		
64-66	10	1	2		11	2		
61-63	4				10	4		
58-60	3	5	1	4	5	1	2	1
55-57	4	1	3		11			2
52-54	3	3	1	2	8	3	1	
49-51	2	1	4	4	12	1	1	
46-48	6		4	3	9	1		
43-45	5		3		9	1	2	1
40-42			3		7		2	
37-39	5		1	1	6	1	1	
34-36	2		4	2	5	1		
31-33	3		2	1	2		2	
28-30			4		5		3	
25-27			4				2	1
22-24			3					
19-21	1		5		1			
16-18			1		2		1	
13-15	1						1	
10-12							1	
7-9							1	
4-6					1		1	
1-3			1					
N	72	33	46	19	145	65	21	7

Appendix B. Distribution of Test Scores. Experiments-Mechanics

Maximum Score = 60 University of Minnesota Fall quarter 1952-53

Score	Physics 1-no laboratory				Physics 1a-with laboratory			
	male		female		male		female	
	pre	post	pre	post	pre	post	pre	post
69-70		1						
51-52								
59-50				1				
47-48								
45-46								
43-44								
41-42								
39-40								
37-38								
35-36								
33-34								
31-32								
29-30		2			1	2		
27-28						2		
25-26		1		1		5		
23-24						3		
21-22		3	1	1	1	9		
19-20	1	1		1	7	7		1
17-18			1	1	2	3		4
15-16	7	3	1	1	5	6		
13-14	2	3			3	5	1	
11-12	1	2	2	2	9	3	1	
9-10	4	4	5	2	13	6		
7-8	5	3	4	2	8	4		
5-6	13	6	6		12	3	3	
3-4	7	2	4	1	14	1	1	
1-2	7	1	4	2	13	3	4	1
-1-0	14		7	2	18		7	
-3-2	5		2	2	16	1	1	
-5-4	2		6		13	1	3	
-7-6	1		2	2				
-9-8	3				3			
-11-10			1		5			
N	72	32	46	21	145	64	21	6

Appendix B4. Distribution of Test Scores. Miscellaneous-Mechanics

Maximum Score = 56 University of Minnesota Fall quarter 1952-53

Score	Physics 1-no laboratory				Physics 1a-with laboratory			
	male		female		male		female	
	pre	post	pre	post	pre	post	pre	post
50-51	1					1		
48-49				1		1		
46-47		3		1	4	7		
44-45					1	2		
42-43		6		1	3	6		
40-41	2	2			5	3		
38-39	4	1	1	1	1	8		1
36-37	9	2	2	3	13	6		1
34-35	3	4			3	4		1
32-33		3	2	1	7	4		
30-31	6	3			17	6	1	1
28-29	5	2		3	3	4		
26-27	6	3	4	1	19	4	1	
24-25	1		1		3	1	1	
22-23	4	1	2	1	8			
20-21	7		6		11	4	1	
18-19	5		2	3	5	2		
16-17	7	2	6		6	2	3	
14-15	3	1	4	1	5		1	
12-13	1		2		6		3	1
10-11	1		2	1	5			1
8-9			2		2		1	
6-7	2		3		6		2	1
4-5			1		2		1	
2-3			2	1	4			
0-1	5		4		6		5	
-2-1								
-4-3							1	
N	72	33	46	19	145	65	21	7

Appendix C1. Distribution of Test Scores, University of Minnesota

Winter quarter 1952-53

Identification of Apparatus-Electricity — Maximum Score = 88

Score	Physics 5* Pre	Physics 5* Post	Physics 8** Pre	Physics 8** Post
64-65				1
62-63				
60-61				
58-59				3
56-57				
54-55		1	1	3
52-53				
50-51				
48-49		2		11
46-47				1
44-45		4	2	10
42-43		1	1	1
40-41		1		2
38-39	1	1		7
36-37			2	1
34-35		3	3	4
32-33				
30-31	1		3	
28-29	1	2	8	3
26-27	3		2	
24-25	4	3	8	3
22-23	2	1	4	
20-21	3	1	5	
18-19	7	3	3	1
16-17	5		4	
14-15	4	1	4	
12-13	4		2	
10-11	5		4	
8-9	3		4	
6-7	1		1	
4-5	1		1	
2-3				
0-1	1		1	
N	46	24	63	51

Function of Apparatus-Electricity — Maximum Score = 108

Score	Physics 5* Pre	Physics 5* Post	Physics 8** Pre	Physics 8** Post
72-73				2
66-67				1
62-63			2	4
60-61				
58-59			1	2
56-57		1	1	11
54-55				
52-53		1	1	13
50-51				
48-49		2		1
46-47		5	3	5
44-45				
42-43		3	1	4
40-41		1	3	
38-39		1	5	
36-37	1	1	2	1
34-35	1	2	1	
32-33	1	3	2	3
30-31	3		2	1
28-29			2	
26-27	3	2	4	
24-25	3		2	
22-23	2		4	1
20-21	3		4	
18-19	2		1	
16-17	5		6	
14-15	1		1	
12-13	4	1	2	
10-11	3			
8-9	2		1	
6-7	3		1	
4-5	1		2	
2-3	2		1	
0-1	3		1	1
-11--1	3		4	1
N	36	23	60	51

* Pre-Medical - Dr. Tucker
** Engineering - Dr. Teng

Appendix C_2. Distribution of Test Scores. University of Minnesota

Winter quarter 1952-53

Symbols-Electricity B
Maximum Score = 60

Score	Physics 5*		Physics 8**	
	Pre	Post	Pre	Post
60-61			1	3
58-59				
56-57				
54-55		3	3	7
52-53				
50-51		4	6	10
48-49				
46-47				
44-45	1	3		6
42-43				1
40-41	1	4		5
38-39				2
36-37		2	1	
34-35	3	1	2	6
32-33	1		2	
30-31	3	6	2	5
28-29			3	
26-27	1		4	
24-25	2		2	2
22-23			2	1
20-21	4	1	2	
18-19			4	
16-17	3		4	1
14-15			2	
12-13	1		3	
10-11	5		4	
8-9	3			
6-7	2		4	
4-5	3		3	
2-3	1		4	
0-1	9		3	2
-2-1	3			
-4-3				
⋮				
-10-9			1	
N	46	24	62	51

* Pre-medical - Dr. Tucker
** Engineering-Dr. Teng

Appendix C3. Distribution of Test Scores. University of Minnesota

Winter quarter 1952-53

	Electrical Circuits Maximum Score = 104					Electrical Meters Maximum Score = 32					
	Physics 5*		Physics 6**			Physics 5*		Physics 6**		Physics 6***	
Score	Pre	Post	Pre	Post	Score	Pre	Post	Pre	Post	Pre	Post
73-75			2	1	32	1	3	4	12	10	27
70-72					28		1			1	2
67-69				1	27		9	5	3	10	14
64-66				1	26						
61-63					25						
58-60				1	24		1				1
55-57					23		1	2	3		1
52-54			1	1	22		8	2	6	8	19
49-51				1	21						
36-48		1		2	20			1	1		
43-45		1	1	4	19					2	
40-42		1		3	18	1				2	1
37-39		2	1	4	17	3	10	6	11	13	18
34-36		1	1	1	16	2	1		1	1	1
31-33			1		15		1				
28-30		2	1	5	14			1		1	
25-27		2	7	5	13	1				2	
22-24			6	8	12	9	6	9	7	11	8
19-21		5	5	6	11	2	1	3	1	2	2
16-18	5	3	2	11	10	1			1		
13-15			11	8	9					3	
10-12	2	1	18	8	8	2					
7-9	3	3	14	12	7	5	2	5	1	13	5
4-6	16	1	14	13	6	3		1			
1-3	4	1	13	5	5	1				2	
-2-0	11		10	2	4	1		1		4	
-2--3	6		4	1	3	1		3		4	
-8--6	1				2	13	3	6	1	8	
-11--9			1	1	1	5	1				1
-14--12			1		0	20		4	1	9	1
-17--15			1		-1	5		1		1	
					-2	3		1			
					-3	4		2	1	7	2
					-4	5		3		1	
					-5	2					
					-6	2					
					-7						
					-8	2	1	3	1	1	
N	48	24	115	104		94	49	63	51	116	103

* Pre-medical - Dr. Tucker
** Engineering - Dr. Teng
*** Engineering - Dr. Johnston